



e!ektor

Arduino

电路与项目指南

(影印版)

Arduino: Circuits & Projects Guide

Günter Spanner 著



东南大学出版社
SOUTHEAST UNIVERSITY PRESS

责任编辑：张 烨
责任印制：张文礼
封面设计：王 玥

Arduino平台的巨大成功至少存在两个原因。首先，价廉物美且可以直接上手的处理器板大大简化了硬件的使用。其次，免费和开源的编程套件无需任何安装过程。

简单的入门级示例确保了快速的成功。对于诸如微处理器版本或者接口设置这样一些参数的复杂选择过程并不是必需的。第一个示例程序可以在几分钟内被上载到Arduino单板上进行测试。Arduino用户有着大量软件库的支持。不过，日益增长的软件库会给新手带来一些问题，在入门级示例之后就会存在一些不确定性。大多数例子缺少详细描述，而描述不足的项目往往让用户更加迷惑而不是起到锻炼的作用。同时这些项目也缺乏清晰的指导和统一的编排，这是因为这些项目是由不同的人创建的，他们往往有着不同的想法。

本书使用了不同的方法。所有的项目都采用了系统化的手段，引导读者进入不同的主题领域。在必须知道的理论方面，着重关注了读者容易接受的实践方向，包括诸如模数转换、定时器和中断这样一些基础的编程技术，它们都被包含在一些动手操作的项目中。本书读者可以创建指示灯、唤醒灯、具备全部功能的电压表、精确数字温度计、多种多样的时钟、反应速度计或者鼠标控制的机械臂。在学习这些项目的同时，读者将能够真正地理解和掌握内在的控制器技术基础知识。

JINODIANLUYUXIANGMUZHINAN ARDUINODIANLUYUXIANGMUZHIN
JINODIANLUYUXIANGMUZHINAN ARDUINODIAN LU
JINODIANLUYUXIANGMUZHINAN ARDUINODIAN
JINODIANLUYUXIANGMUZHINAN ARDUINODIAN
JINODIANLUYUXIANGMUZHINAN ARDUINODIAN
JINODIANLUYUXIANGMUZHINAN ARDUINODIAN
JINODIANLUYUXIANGMUZHINAN ARDUINODIAN
JINODIANLUYUXIANGMUZHINAN ARDUINODIAN
JINODIANLUYUXIANGMUZHINAN ARDUINODIAN
JINODIANLUYUXIANGMUZHINAN ARDUINODIAN

ISBN 978-7-5641-5948-1



9 787564 159481 >

定价：56.00 元

Arduino 电路与项目基础

(第二版)

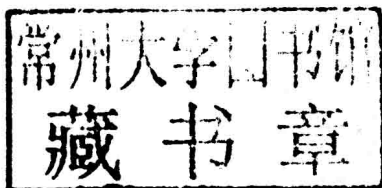
Günter Spanner

鞠

 东南大学出版社
SOUTHEAST UNIVERSITY PRESS

Arduino 电路与项目指南(影印版)

Günter Spanner 著



南京 东南大学出版社

图书在版编目(CIP)数据

Arduino 电路与项目指南:英文/(德)斯潘纳著.
影印本. —南京:东南大学出版社,2015.9

书名原文:Arduino:Circuits & Projects Guide

ISBN 978-7-5641-5948-1

I. ①A… II. ①斯… III. ①单片微型计算机—
程序设计—英文 IV. ①TP368.1

中国版本图书馆 CIP 数据核字(2015)第 178124 号

© 2013 by Elektor International Media BV

Reprint of the English Edition, jointly published by Elektor International Media BV and Southeast University Press, 2015. Authorized reprint of the original English edition, 2015 Elektor International Media BV, the owner of all rights to publish and sell the same.

All rights reserved including the rights of reproduction in whole or in part in any form.

英文原版由 Elektor International Media BV 出版 2013。

英文影印版由东南大学出版社出版 2015。此影印版的出版和销售得到出版权和销售权的所有者——Elektor International Media BV 的许可。

版权所有,未得书面许可,本书的任何部分和全部不得以任何形式重制。

Arduino 电路与项目指南(影印版)

出版发行:东南大学出版社

地 址:南京四牌楼 2 号 邮编:210096

出 版 人:江建中

网 址:<http://www.seupress.com>

电子邮件:press@seupress.com

印 刷:常州市武进第三印刷有限公司

开 本:787 毫米×980 毫米 16 开本

印 张:16.25

字 数:318 千字

版 次:2015 年 9 月第 1 版

印 次:2015 年 9 月第 1 次印刷

书 号:ISBN 978-7-5641-5948-1

定 价:56.00 元

本社图书若有印装质量问题,请直接与营销部联系。电话(传真):025-83791830

Arduino 电路与项目指南(影印版)

About the Author

The author of this book has been active for 16 years in research and development.

The main focus of his work for various major companies, such as Siemens and ABB, is Project Management in the areas of electronic development and physical technology.

Under his leadership and cooperation, several universities have received patents in various fields, from the electronics in environmental sensors to bio- and medical technology.

Thanks to his involvement in the fields of Sourcing Engineering and as Technology and Category Manager, he has detailed knowledge of the semiconductor market and production technology.

Besides his work as a specialist lecturer in physics and electrical engineering, he has published several articles and books on the topics of electronics, semiconductors and microcontrollers, and has created courses and tuition packages on these topics.

Table of Contents

1	Introduction	9
1.1	The Arduino Project.....	10
1.2	Book Structure and Target Audience	10
2	Structure and Function of the Hardware	11
2.1	Lots to Choose From: Arduino Versions	12
2.2	Available for all Purposes: Shields	13
2.2.1	Proto Shield	13
2.2.2	Motor Shield	13
2.2.3	Ethernet Shield.....	14
2.3	Nothing Happens without Power: the Power Supply	15
2.4	The Microcontroller: Heart of the Arduino	15
2.5	The PC Connection: USB interface.....	16
3	Development Environment and Programming Basics	17
3.1	Integrated Development Environment (IDE)	17
3.2	For Linux Users: Arduino IDE Under Ubuntu	23
3.3	Simple Beginnings: The Warning Light.....	24
3.4	General Structure of an Arduino Sketch	24
3.5	Basic Elements of the C Programming Language for Arduino.....	27
3.6	Program Structures.....	29
3.7	Arduino-Specific Functions	29
3.8	Arduino Punctuation: Syntax Elements.....	30
3.9	Data Storage Elements: Variables	30
3.10	The Art of Math: Operators	31
3.11	To Be Clear: Logical Operators.....	32
3.12	Unchanging Parameters: Constants	35
3.13	Dealing with Related Data of the Same Type: Arrays.....	36
3.14	Program Control Structures	36
3.15	Controlling Timing.....	39
3.16	Mathematical Functions	40
3.17	Random numbers	40
3.18	Extending the Options: Adding Libraries.....	41
4	Electronic Components and Low-Cost 'Freeduinos'	43
4.1	Breadboards: Simple and Effective without Soldering.....	43
4.2	Prototyping Boards: Durable Construction without Chemicals.....	44
4.3	Low-Cost 'Freeduinos'.....	45
4.4	Arduino and Its Helpers: Basic Electronic Components	46
4.4.1	USB Cable	46
4.4.2	Resistors	46
4.4.3	Capacitors	47
4.4.4	Potentiometers.....	47
4.4.5	LEDs.....	48
4.4.6	RGB LEDs	48

4.4.7	Switches.....	49
4.4.8	Silicon Diodes.....	49
4.4.9	Transistors.....	49
5	Hello World.....	51
5.1	Cut to the Chaser.....	51
5.2	It Gets Brighter: Controlling Power LEDs.....	53
5.3	POVino: Persistence-of-Vision Display.....	54
6	Displays and Display Techniques.....	59
6.1	Bar Graph Display: The Classic for Measurement Applications.....	59
6.2	Simple and Cheap: 7-Segment Displays.....	59
6.3	4-Digit, 7-Segment Displays: A Key Component for Instrumentation.....	62
6.4	Mini Monitor for Signs and Graphics: The LED Dot Matrix.....	67
6.5	Dot Matrix Display as a Two-Digit Digital Display.....	70
6.6	Micro Learns to Write: Alphanumeric Display.....	72
6.7	The LCD.....	76
7	Measurement and Sensors.....	81
7.1	Flexible and Easy to Read: An LED Voltmeter.....	81
7.2	Volt / Ammeter: Precise Instrument for the Hobbyist's Lab.....	83
7.3	Kiloohmmeter for Specific Applications.....	87
7.4	No More Faulty Electrolytic Capacitor Woes: The 'Elcaduino' Tester ..	89
7.5	'Picofaraduino': Measuring Smaller Capacitances.....	91
7.6	'Transistino': Transistor Tester.....	93
7.7	A Simple NTC Thermometer.....	95
7.8	Hot or Cold? Temperature Measurement Using the AD22100.....	98
7.9	Remote Thermometer.....	99
7.10	'Thermoduino': Precision Thermometer with 7-Segment Display.....	100
7.11	When Are We Most Comfortable? – The Hygrometer.....	105
7.12	'Battduino': Capacity Measurement for Rechargeable Batteries.....	107
7.13	Optical Sensors: Important for More than Just Photography.....	112
7.14	Reflex Light for Geocaching.....	113
7.15	For Professional Photographers: A Digital Light Meter.....	115
7.16	Home 'Radar Station': Distance Measurement Using Ultrasound.....	117
8	Timers, Clocks and Interrupts.....	123
8.1	Morning and Night Fun: Grand Prix Toothbrush Timer.....	123
8.2	Practical and Accurate: Digital Clock with LED Display.....	130
8.3	Who's Faster? A Reaction Timer.....	135
8.4	'Timerino': Universal Timer with a 7-Segment Display.....	138
8.5	Plug-in Timer to Make Life Easier.....	141
8.6	Atomic Precision: The DCF77 Radio Clock.....	142
8.7	Output of Time and Date to the Serial Interface.....	145
8.8	Stand-Alone DCF77 Clock with LCD Display.....	146
9	Interfaces.....	149
9.1	Universal and Simple: The I ² C Interface.....	149
9.2	When We Run Out of Pins: Port Expansion.....	152
9.4	Hexadecimal Debugger Display Using a 2-Digit, 7-Segment Display.....	155
9.5	LCD Control via I ² C Using the PCF8574.....	158
9.6	This Time, Fully Digital: The LM75 Thermometer.....	160
9.7	Power-Saving: Real-Time Clock with Date Display.....	163

9.8	After Including The IRremote Wireless, Practical, Quick: The IR Interface	167
9.9	'Lampino': An IR-Controlled RGB Lamp	171
9.10	Timely Luxury: An IR-Controlled Digital Clock	174
9.11	Optimal for Microcontrollers: The PS/2 Interface	178
9.12	Keyboard and Mouse as Universal Input Devices	178
9.13	A Complete Microcomputer with LCD Monitor and Keyboard.....	181
10	Sounds and Synthesizer	185
10.1	Simple Tones.....	185
10.2	Transducers and Amplifiers.....	187
10.3	Fast PWM Makes It Happen: Not Just tones, But Sound Waves	188
10.4	Theremin: The Contactless Musical Instrument	195
10.5	Audio Processing.....	197
10.5.1	VCO: A Tunable Sine Wave Source	198
10.5.2	Digital Signal Processing	200
10.6	Sound Cloud: A Digital Synthesizer	203
11	Digital Control Techniques	207
11.1	Control Types	208
11.1.1	P Controller.....	208
11.1.2	I Controller	209
11.1.3	PI Controller	209
11.1.4	PD Controller	209
11.1.5	PID Controller	210
11.2	Optimum Workstation Lighting: Digital Illumination Control	210
11.3	A Classic of Control Theory: The Gravity Compensator	214
12	Physical Computing	221
12.1	Servos Control the World	221
12.2	'Photino': 2D Camera Swivel.....	225
12.3	'Cranino': Mouse-Controlled Crane	
13	Processing	231
13.1	Arduino and Processing: A Formidable Team	232
13.2	Interaction with Processing: Data Logging, Trend Graphs, etc.	233
14	The 'Living Room Box': Our Modular Concluding Project	241
14.1	Always Useful: A Clock	242
14.2	Control from Afar: The IR Interface	243
14.3	230 V Control for Hi-Fi systems, Televisions, Lamps, etc.....	243
14.4	Timers and Sensors as the Basis for Home Automation	243
14.5	Indoor and Outdoor Thermometers	244
14.6	No More Dry Air: A Hygrometer	244
14.7	The Hardware.....	244
	Bibliography	249
	Listings	251
	List of Figures	253
	List of Tables	257
	Index	259

101	1.1	Introduction
102	1.2	Basic Concepts
103	1.3	Mathematical Models
104	1.4	Applications
105	1.5	Summary
106	1.6	References
107	1.7	Exercises
108	1.8	Problems
109	1.9	Notes
110	1.10	Appendix
111	1.11	Bibliography
112	1.12	Index
113	1.13	Subject Index
114	1.14	Author Index
115	1.15	Editorial Board
116	1.16	Publication Information
117	1.17	Copyright
118	1.18	Disclaimer
119	1.19	Terms of Use
120	1.20	Privacy Policy
121	1.21	Feedback
122	1.22	Contact Us
123	1.23	Help
124	1.24	FAQ
125	1.25	Legal
126	1.26	Privacy
127	1.27	Security
128	1.28	Accessibility
129	1.29	Language
130	1.30	Units
131	1.31	Conversions
132	1.32	Formulas
133	1.33	Tables
134	1.34	Diagrams
135	1.35	Equations
136	1.36	Proofs
137	1.37	Examples
138	1.38	Problems
139	1.39	Notes
140	1.40	References
141	1.41	Bibliography
142	1.42	Index
143	1.43	Subject Index
144	1.44	Author Index
145	1.45	Editorial Board
146	1.46	Publication Information
147	1.47	Copyright
148	1.48	Disclaimer
149	1.49	Terms of Use
150	1.50	Privacy Policy
151	1.51	Feedback
152	1.52	Contact Us
153	1.53	Help
154	1.54	FAQ
155	1.55	Legal
156	1.56	Privacy
157	1.57	Security
158	1.58	Accessibility
159	1.59	Language
160	1.60	Units
161	1.61	Conversions
162	1.62	Formulas
163	1.63	Tables
164	1.64	Diagrams
165	1.65	Equations
166	1.66	Proofs
167	1.67	Examples
168	1.68	Problems
169	1.69	Notes
170	1.70	References
171	1.71	Bibliography
172	1.72	Index
173	1.73	Subject Index
174	1.74	Author Index
175	1.75	Editorial Board
176	1.76	Publication Information
177	1.77	Copyright
178	1.78	Disclaimer
179	1.79	Terms of Use
180	1.80	Privacy Policy
181	1.81	Feedback
182	1.82	Contact Us
183	1.83	Help
184	1.84	FAQ
185	1.85	Legal
186	1.86	Privacy
187	1.87	Security
188	1.88	Accessibility
189	1.89	Language
190	1.90	Units
191	1.91	Conversions
192	1.92	Formulas
193	1.93	Tables
194	1.94	Diagrams
195	1.95	Equations
196	1.96	Proofs
197	1.97	Examples
198	1.98	Problems
199	1.99	Notes
200	1.100	References

1-8缺页

1

Introduction

There are two main reasons for Arduino's success. The first is the complete processor board, which has significantly eased entry into the microcontroller hardware arena. Typical beginner problems, such as bad power supplies, problems with setting the configuration parameters (fuse bits) and crystals that won't oscillate due to bad load capacitances are all foreign to the Arduino world. The board is simply connected to a PC's USB port, and off we go. People young and old who've never been involved in electronics won't have any difficulty.

The second success factor is the associated programming interface, which is provided as free-of-charge open source software. The second success factor is the associated programming interface, which is provided as free-of-charge open source software. In addition, installation is quick and easy, so the environment is usable immediately. Simple introductory examples encourage rapid progress. The selection of complicated parameters is not required, and the first example programs may be opened and run within minutes.

Furthermore, the Arduino is backed up with a wealth of software libraries, and the number of which grows daily, often presenting beginners with their first problem: after the introduction of simple examples, the way forward is not clear. This is often due to the lack of detailed descriptions and explanations. The number of projects on the internet, which are explained to a greater or lesser extent, is more likely to cause confusion. Because these applications are designed by a number of different people, each with their own goals in mind, there is no common thread connecting them.

That's where this book comes in. Projects are introduced systematically, each introducing a different theme. A practical hands-on approach is employed alongside the necessary theoretical foundations and, in a similar vein, important concepts such as A/D conversion, timers and interrupts are presented using practical projects. There are running lights, fully-functional voltmeters, precise digital thermometers, clocks of all kinds, reaction timers and a mouse-controlled robot crane. Along the way, the reader will gain an understanding of the associated controller techniques and pick them up fully — in the truest sense of the word.

The practical projects presented herein will not be relegated to the status of mere 'laboratory prototypes'. By means of appropriate hints and notes, other practical devices will arise, which may be used for home, hobby and work. The projects are always implemented using easy-to-find and inexpensive components.

In the final chapter, an Arduino-based 'Living Room Box' is presented. It is designed modularly and may be adapted to individual requirements. The knowledge gleaned throughout the book is used practically to produce a very useful, yet unusual, device.

1.1 The Arduino Project

The Arduino concept came to be in 2005 at the Institute for Interactive Design in Ivrea, Italy. The search for a low-cost microcontroller system for design students led to a handy printed circuit board that contained all of the necessary electronic building blocks. The main objective was the development of an inexpensive microcontroller board that could be utilized quickly and simply by art and design students who had no previous knowledge of programming or electronics.

The first version of the Arduino hardware consisted of a kit that could be soldered together easily, and it sold out quickly. Newer versions followed in rapid succession. Designers and artists from other regions took up the idea and the Arduino principle spread, first in Italy, then into Europe, and eventually to the rest of the world.

Interest grew rapidly in application areas outside of art academies and design schools. The concept of a simple and low-cost hardware platform with a freely available, easy-to-learn programming language was quickly embraced by hobbyists. Finally, schools and universities in the scientific and technical fields recognized the enormous potential of the Arduino idea. New hardware versions, as well as plug-in expansion boards, or 'shields', arose, and Arduino application areas were limited only by users' imaginations.

Meanwhile, the number of Arduinos shipped has exceeded the 100,000 mark by far. If DIY versions and clones are considered as well, the actual figure may exceed 1 million. It is, therefore, no exaggeration to claim that the Arduino microcontroller board is the most successful of all time.

1.2 Book Structure and Target Audience

This book is aimed at those who've already had some basic experience in the electronics field. The typical high school lessons on circuits, Ohm's law, etc., are fully sufficient. In Chapter 4, the basic functions and characteristics of the major components are explained. In due course, more elaborate projects are discussed, so that even students and teachers who come with some pre-existing technical knowledge will encounter new challenges.

The projects are grouped into individual themes. However, care was taken to place the less technically challenging material at the beginning of the book. For this reason, beginners will find it helpful to go through the book's chapters in order, even if not every single project is constructed.

2 Structure and Function of the Hardware

In its original form, the Arduino board was fitted with an ATmega8 microcontroller and a simple RS-232 level converter. In this way, it could be programmed directly from a PC's serial port. Over time, a variety of updates and versions has evolved from this prototype. Since fewer and fewer PCs came equipped with this legacy interface over the years, one of the first major steps in Arduino development was the addition of a USB-to-RS-232 converter. At first, an FTDI chip was used. Later, on the Arduino UNO board, this relatively expensive chip was replaced by an ATmega8U2. Using suitable firmware, this chip is able to manage USB-to-RS-232 protocol conversion.

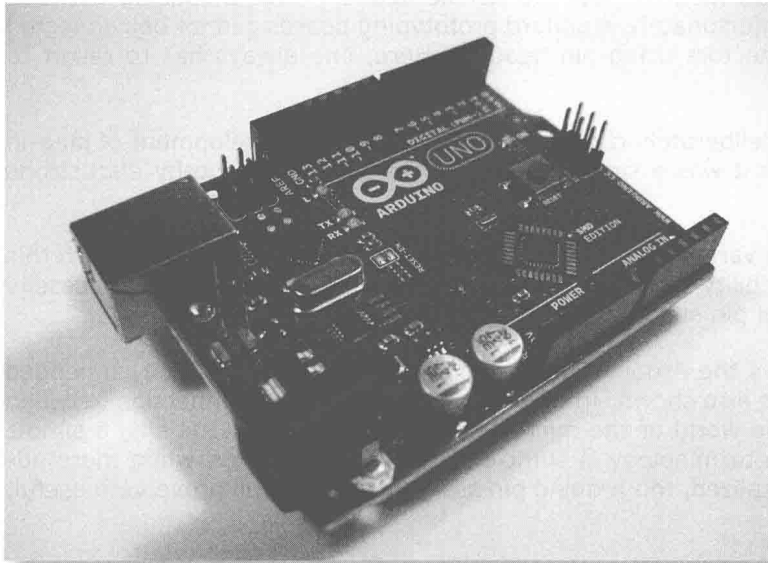


Figure 2.1:
Arduino Uno SMD

The original ATmega8 processor was also replaced by the more powerful ATmega168 and ATmega328 variants. In parallel with the main line of development, several more-or-less compatible offshoots have emerged over the years. For example, there are rugged versions in which all ports are specially protected against overvoltage and short circuits, and special versions with custom form factors and pin spacings.

2.1 Lots to Choose From: Arduino Versions

Besides the basic Arduino reference design, there are many other versions in various sizes and form factors. Examples include the Arduino MEGA, equipped with an ATmega1280 or ATmega2560. These processors have a much wider range of functions and a significantly greater number of available pins. Due to the greater pin count, the boards are roughly double the size of the classic Arduino.

On the other end, if you want to build small, compact devices, you can go down to the Arduino Mini or Arduino Nano devices, which are each roughly the size of a postage stamp. Instead of connector sockets, they have only solder pads, onto which cables may be directly soldered. Alternatively, pin headers may be attached, so that these compact boards may be plugged directly into breadboards or IC sockets.

The LilyPad is also of particular note, characterized by its special form factor — not a regular rectangular circuit board but a circular disc. The main application area for this interesting Arduino variant is in the field of 'wearable computing', in which the LilyPad is sewed into articles of clothing and connected to LEDs, sensors or actuators via thin wires or conductive threads.

Finally, the 'pin spacing dilemma' should be mentioned. Unfortunately, in the development of the classic Arduino, not all of its connectors were aligned to the common 1/10" (2.54 mm) grid spacing. In fact, the top two female headers have a spacing between them of only 1/20", so, unfortunately, standard prototyping boards cannot be connected directly to all of the connectors using pin headers. Here, one always has to resort to work-around solutions.

Whether this layout was deliberately chosen to prevent the easy development of plug-in replica shields or whether it was a simple oversight has stirred up lengthy discussions on internet forums.

Meanwhile, other Arduino variants that followed have also been manufactured with this aesthetic flaw, as compatibility with the many preexisting shields dictates the necessity of maintaining the original pin spacing.

The following figure shows the Arduino pin assignments. The names of the embedded microcontroller's ports are also shown. In this way, we make a clear connection between the Arduino world and the world of the microcontroller professional. Initially, a simple understanding of Arduino terminology is sufficient. Later on, however, when more advanced applications are realized, the Arduino pin assignment map will prove very useful.

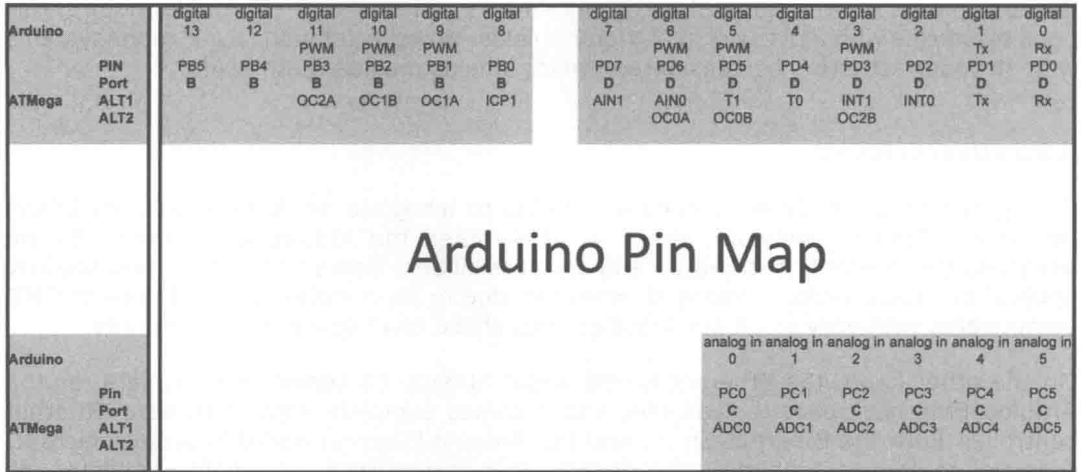


Figure 2.2: Arduino Pinout

2.2 Available for all Purposes: Shields

Plug-in modules for the Arduino are called shields, and they greatly expand the board’s functionality. There are over 100 different types of shields available, ranging in functionality from simple prototyping to Ethernet connection, XBee wireless, motor drivers, to color graphics display shields. What follows is a brief description of the most important and best-known shields.

2.2.1 Proto Shield

There are many different varieties of this shield. In the simplest case, a proto shield consists of a stripboard with two soldered pin headers. The only difference from an ordinary stripboard is that the second digital connector is spaced appropriately from the first, specifically for the Arduino (see ‘pin-spacing-dilemma’ in the previous section), and the module can thus be connected without any mechanical obstacles.

Other variations include solderless breadboards, with which simple prototypes may be quickly and robustly created.

It isn’t very difficult to create suitable DIY shields, so one should decide whether the situation merits the purchase of a more expensive proto shield.

2.2.2 Motor Shield

These have various power drivers to enable the control of different types of electric motors. Depending on the version, DC and stepper motors may be driven. These boards usually have screw terminals that enable the connection of the thicker motor wires securely.